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Aggregate for Truck Arrester Beds

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Abstract

In 1994, MTO (Ministry of Transportation of Ontario) constructed a truck arrester bed in the City of North Bay. This paper describes the research and investigation of the gravel used to fill the bed, and the full-scale testing and further investigation that took place subsequent to construction.

The desirable properties of truck arrester bed gravel are a large proportion of rounded particles and a mean sphericity that should approach 1 as closely as possible. The grading used was 100% pass 37.5 mm with no more than 5% pass the 16-mm sieve. Suitable deposits of rounded and spherical stone were found within about 100 km of the construction site. Testing was conducted on frozen gravel in the laboratory, which showed that strength when frozen was low provided that moisture/ice content was low. To keep moisture content low, it is important to ensure absolute cleanliness of the gravel. In full-scale tests with trucks, the bed worked as intended and produced a rolling resistance of about 0.25.

Difficulties have been found in two areas: keeping debris from entering the bed that is directly adjacent to the travelled lanes of the highway and frost build-up in the bed under certain conditions for part of the year. It is doubtful that a gravel aggregate arrester bed could be designed that would reliably work throughout the year in a severe winter climate. Because of this concern a contract has been prepared to replace the current arrester bed with a dragnet system.

Key Words

Aggregate, grading, gravel, particle shape, rounded particles, spherical particles, testing, truck arrester bed

Distribution

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Executive Summary

In 1994, MTO (Ministry of Transportation of Ontario) constructed a truck arrester bed in the City of North Bay. This paper describes the research and investigation of the gravel used to fill the bed, and the full-scale testing and further investigation that took place subsequent to construction.

The desirable properties of truck arrester bed gravel are a large proportion of rounded particles and a mean sphericity that should approach 1 as closely as possible. The grading used was 100% pass 37.5 mm with no more than 5% pass the 16-mm sieve. Suitable deposits of rounded and spherical stone were found within about 100 km of the construction site. Testing was conducted on frozen gravel in the laboratory, which showed that strength when frozen was low provided that moisture/ice content was low. To keep moisture content low, it is important to ensure absolute cleanliness of the gravel. In full-scale tests with trucks, the bed worked as intended and produced a rolling resistance of about 0.25.

Difficulties have been found in two areas: keeping debris from entering the bed that is directly adjacent to the travelled lanes of the highway and frost build-up in the bed under certain conditions for part of the year. It is doubtful that a gravel aggregate arrester bed could be designed that would reliably work throughout the year in a severe winter climate. Because of this concern, a contract has been prepared to replace the current arrester bed with a dragnet system.

Aggregate for Truck Arrester Beds

1.0 INTRODUCTION

In 1994, MTO (Ministry of Transportation, Ontario) constructed a truck arrester bed at the north entrance to the City of North Bay. This paper describes the research and investigation that took place prior to construction, and the full-scale testing and further investigation that took place subsequent to construction. The total tender price was about \$4.4M, which included the construction of the arrester bed, production, and placement of about 4000 tonnes of special gravel and construction of asphalt pavement, concrete barriers, overhead signs, and other associated work.

Thibault Hill, in the City of North Bay, is not an extremely steep or long hill. However, it has unique features that justified the choice of a truck arrester bed. This is a hill with an elevation change of about 100 m on the eastbound TransCanada Highway at the north entrance to the city. At the immediate bottom of the hill is a series of traffic lights and an urban area with considerable congestion and vehicle turning activity. This is the first hill for many kilometres where there is a requirement to come to a stop at the bottom. There had been a number of incidents of truck brakes failing or fading and the uncontrolled travel of trucks through stoplights and the urban area with a number of associated collisions. A coroner's jury in 1986 had recommended that the construction of such a facility be investigated, following a fatality at this location. There was no space at the bottom of the hill, before the first traffic control light, to establish an escape ramp. There was also no opportunity to establish a gravity ramp (uphill escape ramp with or without an arrester bed). A further complication was an elementary school on the west side of the highway at the bottom of the hill and it was desired to shift trucks, especially runaway trucks to the east away from the school area. As a result, an arrester bed was designed that would be on the downgrade and on the left side or normal passing lane of the divided highway. It was also conceived to function as both a side entry arrester bed and a conventional top entry bed. The bottom of the bed was lined with an impermeable membrane. The runoff from the bed led downgrade to a reservoir that would capture any spilled fuel in the event of a tank rupture. This also had the advantage of providing positive drainage of precipitation onto the bed. It is not the purpose of this paper to examine in detail the issues with the design and construction, but to focus on the properties of the aggregate and the subsequent performance of the aggregate in the arrester bed.

The climate of North Bay is severe, the average date of the first frost in the fall is in mid September, and the date of the last frost is late May. The mean temperature in January is about -13°C (1961-1990 data), and there are five months when the mean daily temperature is below 0°C. The annual mean precipitation is about 97 cm spread throughout the year. The low temperatures and significant amounts of precipitation meant that a truck arrester bed had to be designed so that it would work as intended when frozen and also under a blanket of snow (the median snow depth at the end of February is about 51 cm or 20 inches).

1.1 CONCEPT OF TRUCK GRAVEL ARRESTER BEDS

Pagan (1989) reviewed the issue of emergency escape ramps and noted that there were three types in common use: gravity ramps, sand or gravel arrester beds, and gravity ramps with arrester beds. The location of the proposed facility in North Bay precluded a gravity ramp. (It was a downhill grade with no potential for an uphill ramp.) A sand bed was rejected because of the cold climate and freezing that would take place of partially saturated sand would render the bed inoperable for about half the year.

The Ministry of Transportation conducted a design review of the best geometry of the bed to be constructed in North Bay (Jankowski, 1989). In concept, when a truck enters an arrester bed, the trucks kinetic energy is dissipated through the transfer of momentum to the aggregate by the rolling wheels and by overcoming the aggregate shear resistance, which depends on the interparticle friction. It might be thought that high interparticle friction would be desirable but such is not the case. Low interparticle friction is needed so that the truck wheels sink deeper into the bed and, as a result, more energy is transferred. Also, as the truck sinks into the bed, if the aggregate is of sufficiently low shear resistance, the axles will drag on the upper surface further slowing the truck. The lower the interparticle friction, the more rapid the slowing of the truck. It was recognized that, in winter conditions, the contamination by ice control sand and water that might accumulate and freeze at the bottom of the bed would stop it functioning through the full depth. So, although theoretically, only a depth of about 450 mm was required, the bed was designed with a depth of about 600 mm with side slopes of 2:1 and a taper at the upper or entry end.

Wang (1989) summarized the two conditions necessary for a gravel bed to work: They must have low interparticle friction sufficient to for vehicle wheels to sink into the gravel and must be free draining. This is achieved by having smooth rounded particles of substantially the same size with little or no sand or smaller or larger size particles. Another critical requirement is that the aggregate be resistant to both degradation by abrasion and freezing and thawing.

1.2 DESIRABLE AGGREGATE CHARACTERISTICS

A number of characteristics determine interparticle friction: sphericity, roundness, and surface texture. Surface texture is difficult to measure but is determined by the grain size of the rocks and the degree of polish given by interparticle grinding. Grading, of course, is also important; poorly graded material preferably of a single sieve fraction is needed to reduce the stability of the material.

SPHERICITY

Sphericity is extremely difficult to measure. We chose the procedure advocated by Wang (1989), which gives an approximate measure. The three principle axes of an aggregate particle are measured with a caliper. To get a good estimate of the mean sphericity of aggregate, at least 200 particles need to be measured and the average calculated. The axes measured are the longest, the

intermediate and the shortest with the axes being at 90° to each other. $S = \text{the cube root of } bc/a^2$: where S = sphericity, a = longest axis, b = intermediate, and c = shortest. When $S = 1$, the particle is perfectly spherical.

A modification of this method that obtains similar results is the measurement of the maximum dimension to the minimum dimension ($a/c > 2$) which can be thought of as 'long' particles. The amount of long particles that exceed the ratio of 2 can be limited by specification. In the field or laboratory, this is a far easier and more rapid test, and is probably to be preferred as a practical specification test. Long particles in per cent were not specified in the contract but were subsequently investigated so as to aid in writing a future specification.

Whichever shape measurement technique is used, the concept is that gravel made up of a high proportion of spherical particles will have a higher void space, lower internal friction, and, thus, give a more efficient gravel arrester bed than one made with a low proportion of spherical particles.

ROUNDNESS

It is also important that the particles have a rounded shape. There should be few or no fractured or crushed surfaces or sharp edges. This is the opposite of what is normally desired in a granular base aggregate where fractured or crushed particles are desired to give good particle interlock, and, hence, satisfactory stability. Being rounded is not the same as being spherical. A cube has equal principle axis lengths and, thus, has a sphericity of 1, but such a particle is not going to have the desirable properties of roundness for use in a truck arrester bed.

Figures 1, 2, and 3 show pictures taken from the MTO standard test for determination of percent crushed particles (MTO LS-607). Figures 1 and 2 show what are defined as uncrushed particles but are not judged to be sufficiently rounded to meet the roundness definition. Figure 3 shows images of rounded particles that were used in specifying rounded particles for the purposes of supply of truck arrester bed aggregate. Roundness is hard to define with words and a picture gives a much better understanding.

1.3 INVESTIGATION OF AGGREGATE SOURCES

Gravel sources within a radius of about 160 km were sampled and tested. Within any general area, only one or two sources were sampled. This was because the nature of gravel within each of these areas was generally very similar. The origin of gravel deposits in this part of Ontario is from glaciofluvial outwash, delta, and ice contact deposits. These deposits have typically formed within the last ten to twelve thousand years. The rock found in the deposits was composed of Precambrian age foliated gneisses of granitic to dioritic composition with lesser amounts of non-foliated granites and diorites. There was one exception to this, which was a source near Thessalon that contained about 50% Precambrian sediments composed of argillite, greywacke, and sandstone. Materials were tested for grading, shape, resistance to abrasion using the Los Angeles abrasion and impact test, petrographic examination using Petrographic Number (Rogers, 1990), unit weight, and bulk relative density.

The results of shape testing of the sources are shown in Figures 4 and 5. The samples from North Bay and Huntsville had the poorest shape because they contained the highest proportion of strongly foliated gneisses. The foliation gave the particles an elongated rather than cubical shape. The sample from Thessalon also had relatively poor shape due to the presence of the sedimentary rocks that often had a tabular shape. The two MTO sources were of most interest. They were located within about 10 km of each other and had very similar geologic composition. However, they were found in deposits of different glaciofluvial origin. The Deux Rivieres source was topographically lower than the Randon source by about 100 m and represented material from a relatively lower energy regime. The Randon source represented material that had been transported in a very high-energy environment. This was a coarse-grained outwash deposit formed during a time of enormous water flow down the Ottawa River during the melting of the ice and discharge of water from glacial lakes of the last ice age. The Randon pit contained large rounded boulders (up to 0.5-m diameter) that could only be transported in a high-energy environment. The Randon material had significantly better sphericity and rounding than any other source that was investigated. This was the material that was ultimately selected by the contractor for supply of the truck arrester bed gravel.

1.4 SPECIFICATION FOR ARRESTER BED GRAVEL

The supply of the arrester bed aggregate was governed by a special provision to the contract that specified the material characteristics and defined the quality assurance process. The contract documents also provided a list of aggregate sources within a radius of about 100 km that were capable of supplying stone that would likely be capable of meeting the specification requirements. Two sources owned by the MTO, which were available free of charge, were shown as containing material capable of meeting the contract requirements and also containing sufficient material. The other sources were commercial. It was noted that a crusher could not be used for production of acceptable stone. The quality assurance process required testing of 1000-tonne lots with four equal sublots, each represented by one random sample that would be subjected to full testing. After placement of material in the bed, it was to be covered to prevent the ingress of foreign materials during any subsequent construction work.

The specification initially proposed for production and acceptance of material for the truck arrester bed is shown in Table 1. The rate of production of the rounded gravel from the Randon pit was extremely slow because the gravel source only contained an estimated 5% of the desired sizes. The grading requirements were modified after consultation with the contractor to the modified values shown in Table 1. There were no requirements for abrasion loss or resistance to freezing and thawing. This was because the material had been tested prior to letting of the contract and the materials were known to be resistant to frost and reasonably resistant to abrasion (Los Angeles Abrasion and Impact loss of about 43%).

1.5 LABORATORY INVESTIGATIONS OF FROZEN STRENGTH

Following production of material for the truck arrester bed from the Randon source, two series of tests were conducted to investigate the frozen strength of the aggregate:

In the first series, material sampled from the arrester bed was compacted in three layers in 150 x 300 mm concrete cylinder moulds. Each layer was lightly sprayed with water and rodded 25 times with a concrete tamping rod. The cylinder was then frozen at -18°C for a minimum of 48 hours. The cylinder of frozen aggregate was demolded by briefly placing the cylinder mould in water, taking care that no water flooded over the open top. The cylinder was inverted and the frozen cylinder of gravel removed, capped with soft neoprene caps, and immediately tested in compression at a rate of about 0.009 Mpa/sec. Following failure, the material was weighed, oven dried, and weighed again to determine moisture content, and sieve analysis conducted to determine gradation. The results are shown in Figure 6. It can be seen that increasing amounts of material finer than 16 mm generally resulted in higher frozen strength.

In the second series, material from a stockpile of arrester bed aggregate was sampled. Test samples were made as described above, however, after the material was frozen, it was removed from the freezer and lightly sprayed with water at about 4°C and returned to the freezer. This was repeated a second time. The intention was to simulate a series of periods of rain followed by freezing without substantial melting of ice around the arrester bed aggregate. This would simulate conditions that might occur early or late in the winter season. In this case, the frozen material was tested at a rate of 0.039 MPa/sec, since the earlier series was taking too long to fail and melting of ice on the outside of the frozen cylinder was taking place. Following failure, the material was weighed, oven dried, and weighed again to determine moisture content, and sieve analysis conducted to determine gradation. The results are shown in Figure 7. This shows that strengths were higher than in Series 1 due to greater amounts of ice caused by the repeated water applications. It also shows that the amount of material passing the 19-mm sieve was moderately correlated with strength.

Figure 8 shows strength against moisture content for both Series 1 and 2. As would be expected, there is a direct correlation between moisture content and strength. The more ice, the stronger the frozen material. For the material to work as intended in winter conditions, it is necessary that the moisture content be as low as possible. This, in turn, is related to the ability to drain water and the cleanliness of the aggregate. Any material, such as sand, that coats the rounded particles will tend to hold water by capillary action. An examination of the grading of the material from Series 1 showed that the majority of the material passing the 16-mm sieve was sand with content by mass ranging from about 2% to 8%. In the case of Series 2, the sand content ranged from about 1% to 4%. The higher strength in this series is due mainly to the repeated wetting and freezing cycles rather than contamination by fine material.

1.6 FULL SCALE TESTING

Following installation of the truck arrester bed (Figure 9), full scale testing was made with a 4-axle, 20-tonne tractor-trailer combination owned by MTO. The driver was highly experienced and wore a helmet. The trailer/truck combination was also fitted with anti-jackknife chains. The truck entered the bed at a variety of speeds and the bed performed as expected, stopping the truck in a short distance that increased as entry speed increased. Distance to full stop was measured. The rolling resistance was calculated as an average of about 0.25. After each entry, the truck was removed by using a large tow truck, with wooden planks under the wheels of the tractor and trailer to aid the exit.

One of the observations made when the MTO truck entered the bed was that the front axle sunk into the bed and then rapidly bounced out of the bed resulting in a "porpoising" effect. This had been previously observed by Wambold et al (1985) who attributed the cause as follows: "... is that the truck sinks into the gravel as far as possible where it encounters a large retarding force. The tires then follow the path of least resistance by riding on top of the gravel before repeating the process." The effect was found to be more severe in higher speed tests.

Another observation was that the majority of the slowing took place by the embedment of the tractor wheels in the gravel. The trailer wheels showed relatively small amounts of retardation because they travelled in the groove already made by the wheels in front. The driver reported that the anti-jackknife chains only acted on one entry for a short period. There was little tendency to jackknife.

1.7 MICROCLIMATE IN WINTER

In late 1998, temperature probes were inserted at various depths in the bed to gain information about the temperature during the winter. Readings were taken at about midday on a weekly basis from January to April of 1999 and from December to February of 1999/2000. The data for early 1999 is shown in Figure 10. It can be seen that the temperature of the gravel in the arrester bed was often above freezing but the air temperature was considerably colder. This was due to the insulating effect of snow cover. The data for late 1999, shown in Figure 11, shows that the gravel was frozen although it was slightly warmer at the bottom of the bed. In December 1999, there was a lot of rain, which froze in the upper layers of the bed that was then covered by snow and remained frozen. In mid-February 2000, the bed was explored with a backhoe in three locations, where it was found that the upper 300 mm was well frozen (Figure 12) with considerable amounts of ice. Below about 300 mm, the bed was still relatively loose. The backhoe was able to drive without difficulty on the surface of the arrester bed. It was postulated that water vapour moved from the bottom of the bed to the colder and frozen upper layers where ice build-up occurred rather like ice build-up on cooling coils of a freezer.

The agreed opinion of those familiar with the bed was that clean large stone was a better solution to the problem of freezing than smaller size pea gravel but the ice build-up under specific winter conditions was unexpected and rendered the bed temporarily ineffective under those conditions.

1.8 NEED TO CLEAN THE BED

In the cold climate of Ontario, considerable amounts of ice control sand are used in the winter season to improve friction, especially on hills. MTO uses an annual average of about 16 tonnes of sand for each lane kilometre. A considerable amount of sand has been found to enter the bed. In late 1998, after three winters, testing showed that between 14.6 and 5.4% of material passed the 16-mm sieve, 8.5 to 2.9% passed the 4.75-mm sieve, and the material finer than 75 μ m ranged from 0.8 to 1.7%. The greatest amounts of finer material were found at the upper end of the arrester bed that had probably washed down hill and into the bed. In general, the upper 200 mm looked clean and free of sand, probably due to rainfall. Below 200 mm, greater amounts of sand were found. The truck arrester bed aggregate has been removed on three separate occasions, washed to remove the sand, and returned to the bed. This has been moderately difficult, and

expensive, because of the care needed to ensure that the impermeable membrane was not damaged.

Many jurisdictions have noted that they need to periodically 'fluff' the bed with a backhoe or gradall to ensure so that it maintains its stopping ability that may degrade due to settling and consolidation of the aggregate. Because of the relatively single size grading and the rounded nature of the gravel used in North Bay, it has not been found necessary to carry out this kind of periodic maintenance more than about once yearly.

1.9 USE BY RUNAWAY TRUCKS

In September 2003, a truck entered the bed and was stopped as designed. It appears that the trucker had not heeded the warnings at the approach to the bed and pulled to the left to overtake a slower truck and entered the bed from the upper end. The materials were not frozen. It is not thought that the brakes had failed. As found in earlier testing, the tractor wheels became deeply embedded, but the trailer wheels showed relatively little embedment and travelled in the grooves made by the wheels in front. This is shown in Figures 13, 14, and 15.

1.10 OTHER SPECIFICATIONS

Few agencies have published formal specifications for Truck Arrester Bed aggregate. In particular, there is a paucity of information on desirable properties of gravel for use in severe winter climates. Colorado (1993, personal communication) noted that they had no formal construction specification because maintenance forces built these beds. They required 100% uncrushed materials, 100% pass a 50-mm sieve; with 0-15% pass a 19-mm sieve, and 0-3% pass a 4.75-mm sieve. An earlier Colorado report (Hayden, 1982) gave alternative requirements of 100% pass a 1-inch sieve, 90-100% pass a 3/8-inch sieve, 0-15% pass #4 sieve, 0-5% pass #8, and 0-1% pass #200. Allison *et al* reported that a gravel arrester bed in New York had about 97-99% pass 12.7-mm sieve with 1.0-11.6 passing the 6.3-mm sieve.

In 1999, subsequent to the construction of the arrester bed in North Bay, we obtained samples and tested gravels from an arrester bed in New York, three locations in British Columbia, two locations in Idaho, and one in Washington State. These materials showed a variety of gradings but all were substantially coarser than 4.75 mm and finer than 37.5 mm. The amount of long particles ($a/c > 2$) is plotted against rounded particles in Figure 16. It can be seen that, of all the materials studied, the material used in North Bay has the highest amount of rounded particles and the lowest amount of long particles. This is not quite the complete picture in determining rolling resistance however. Grading and particle surface texture play an important part in determining interparticle friction. Gravel of relatively poor shape but which is highly polished (like marbles) may also have relatively low interparticle friction. Surface texture was not evaluated in this study of gravel from arrester beds owned by other agencies.

1.11 SUGGESTED SPECIFICATION

A final specification developed for construction of truck arrester beds is shown in the appendix. A Los Angeles Abrasion and Impact loss requirement could also be required, however, the gravel that was used in the truck arrester bed gave losses in this test of about 43% and has not degraded in use in this application.

2. CONCLUSIONS

The desirable properties of truck arrester bed gravel are a large proportion of rounded particles and a mean sphericity that approaches 1 as closely as possible. The grading used was 100% pass 37.5 mm with no more than 5% pass the 16-mm sieve. Suitable deposits of rounded and spherical stone were found within about 100 km of the construction site. Testing was conducted on frozen gravel in the laboratory, which showed that strength when frozen was low provided that moisture/ice content was low. To keep moisture content low, it is important to ensure absolute cleanliness of the gravel. In full-scale tests with trucks, the bed worked as intended and produced a rolling resistance of about 0.25.

Difficulties have been found in two areas: keeping debris from entering the bed, which is directly adjacent to the travelled lanes of the highway, and frost build-up in the bed under certain conditions for part of the year. It is doubtful that a gravel aggregate arrester bed could be designed that would reliably work throughout the year in a severe winter climate. Because of this concern a contract has been prepared to replace the current arrester bed with a dragnet system.

Acknowledgments

A large number of people have been involved in various aspects of selecting and evaluating the gravel for this project. In particular, I would like to acknowledge the fine work of Dave Williams and Bob Gorman in finding and testing suitable aggregate sources, Janet Curtis, an EIT with our office, who conducted the frozen gravel compression strength tests, and Brian Schubert, who monitored the temperature of the arrester bed in the winter.

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Table 1. Specification Used on Contract 93-213 to Supply Truck Arrester Bed Aggregate and Data for Production Samples

Laboratory Test	Original Specification	Modified Specification	94-45074	94-45075	94-45076
Petrographic Examination (PN)	160 (max)	160 (max)	117	127	144
Spheroidal Particles	50 (min)	50 (min)	66	71	63
Rounded Particles	30 (min)	30 (min)	45	41	44
Loss by Washing, 75 μ m	1.0	1.0	0.40	0.41	0.42
Gradation: % Pass 37.5 mm	100	100	99.4	100	100
% Pass 26.5 mm	90 (min)	-	36.6	46.9	38.6
% Pass 22.4 mm	-	-	19.5	23.1	20.7
% Pass 19.0 mm	10 (max)	-	7.3	7.5	6.2
% Pass 16.0 mm	2 (max)	5 (max)	5.5	5.6	4.8



Figure 1. Uncrushed particles (chipped only)

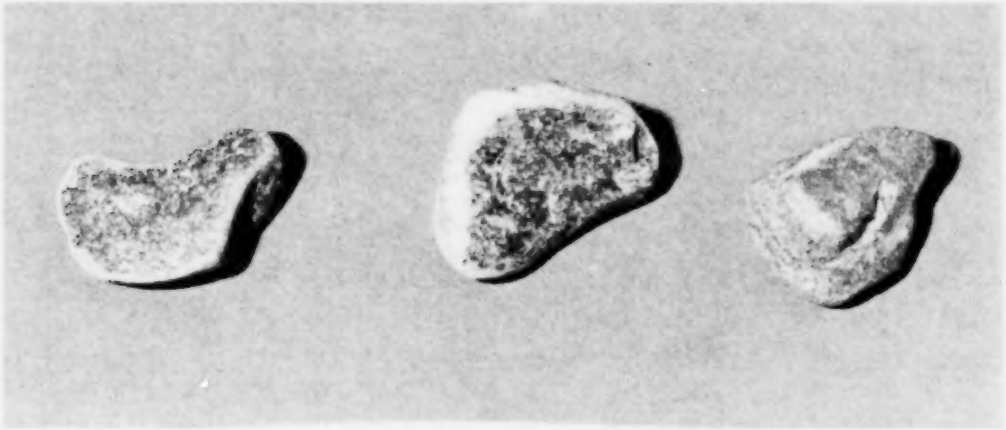


Figure 2. Uncrushed particle (round edges, smooth surfaces)



Figure 3. Uncrushed particle (rounded particles, smooth surfaces)

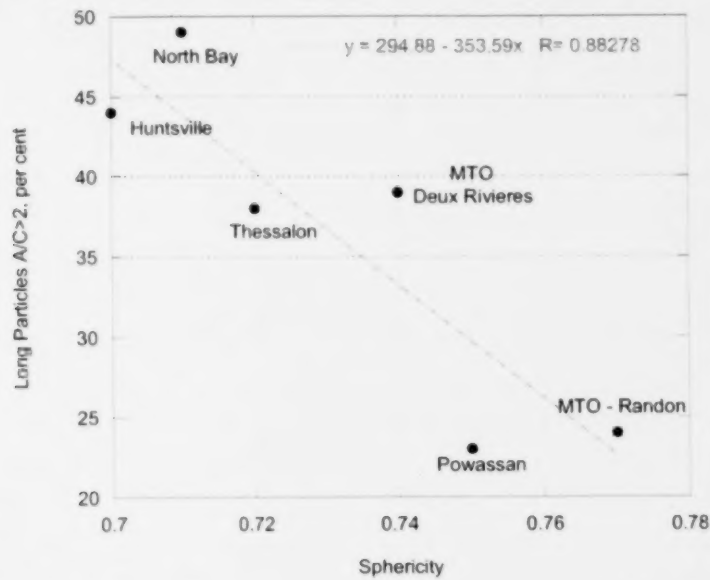


Figure 4. Long particles (A/C>2) against mean sphericity for 26.5 to 22.4 mm material for gravel sources investigated for use as truck arrester bed aggregate

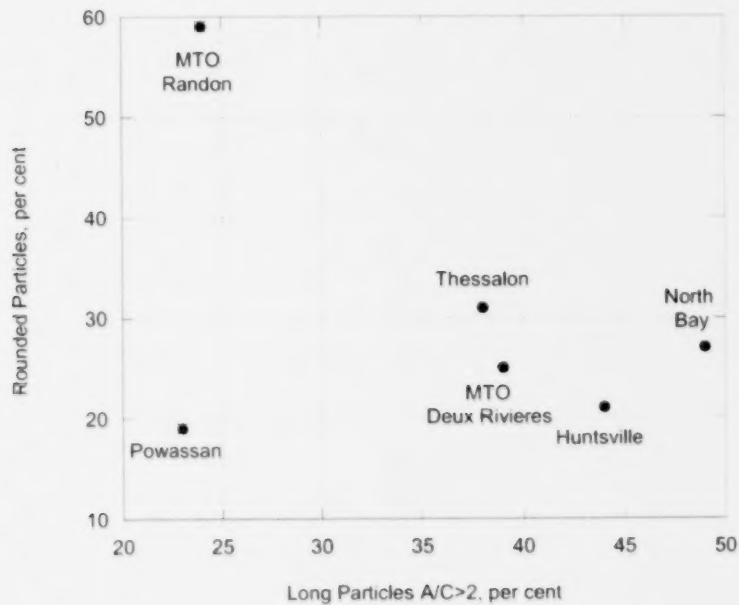


Figure 5. Rounded particles against long particles for 26.5 to 22.4 mm material for gravel sources investigated for use as truck arrester bed aggregate

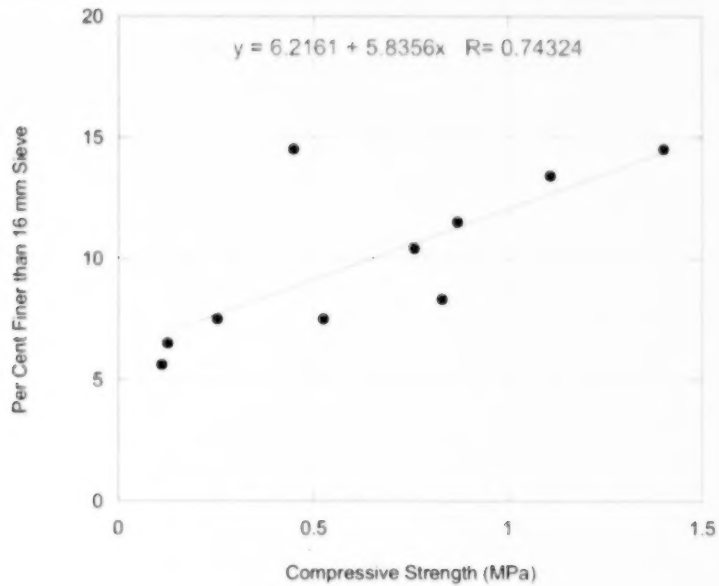


Figure 6. Compressive strength for frozen cylinders of truck arrester bed aggregate as a function of material finer than 16 mm. One episode of wetting and freezing – Series 1

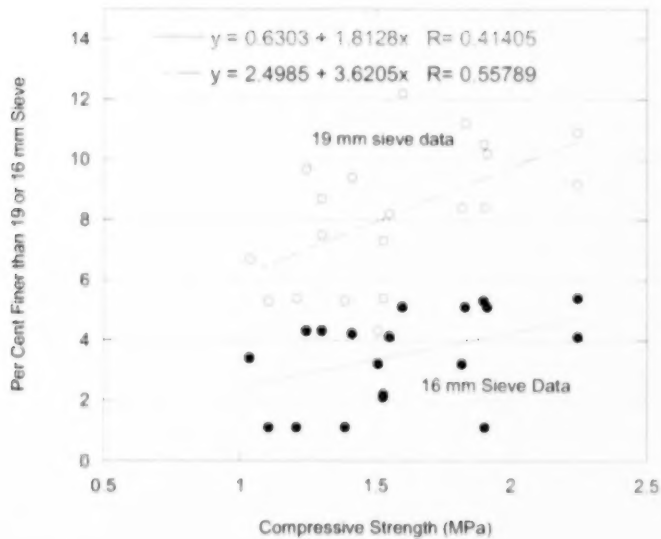


Figure 7. Compressive strength for frozen cylinders of truck arrester bed aggregate as a function of material finer than 19 or 16 mm. Three episodes of wetting and freezing – Series 2

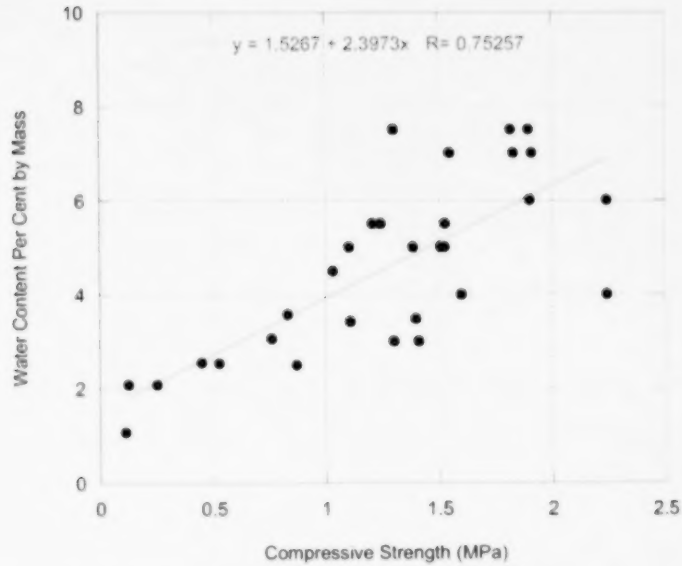


Figure 8. Compressive strength for frozen cylinders of truck arrester bed aggregate as a function of water/ice content



Figure 9. Appearance of truck arrester bed aggregate disturbed by entry of truck. Note sand adhering to some particles from lower in the bed.

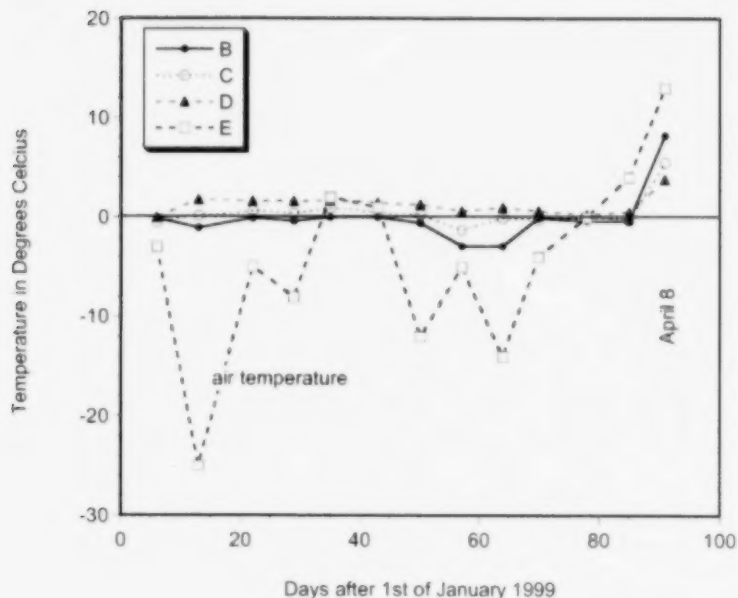


Figure 10. Microclimate of arrester bed from early January 1999 onwards. B = temperature at depth of 50 mm, C = temperature at depth of 200 mm, D = temperature at depth of 400 mm, E = air temperature

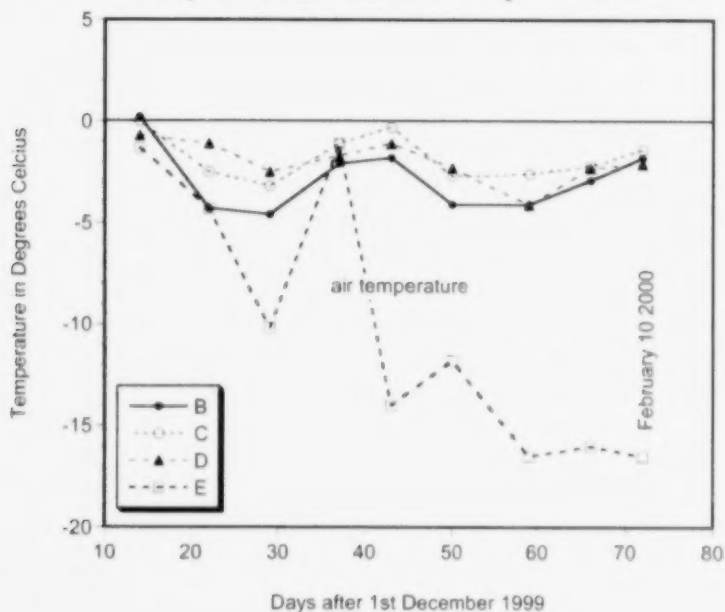


Figure 11. Microclimate of arrester bed from early December 1999 until mid-February 2000. B = temperature at depth of 50 mm, C = temperature at depth of 200 mm, D = temperature at depth of 400 mm, E = air temperature

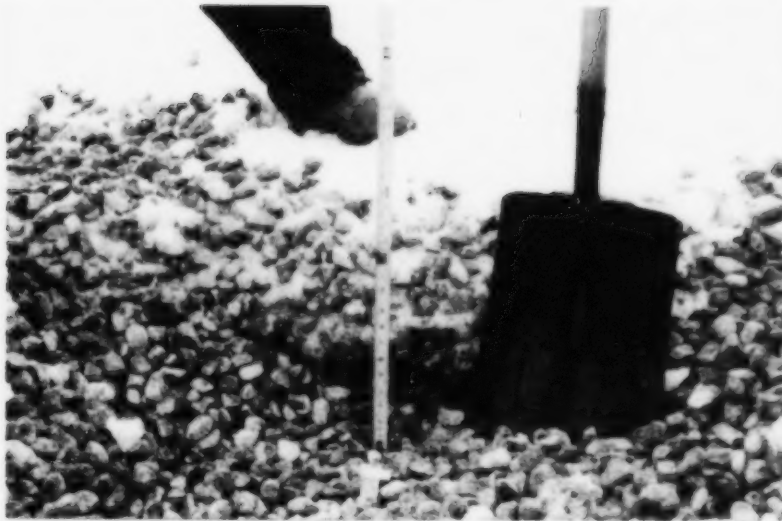


Figure 12. On March 10, 1999, the upper 300 mm was well frozen.



Figure 13. Truck embedded in gravel bed in 2003. Note two front axles show greater embedment than third axle.



Figure 14. View from rear showing deep grooves caused by passage of wheels in the gravel.



Figure 15. Two cranes were used to lift the tractor and trailer from the bed.

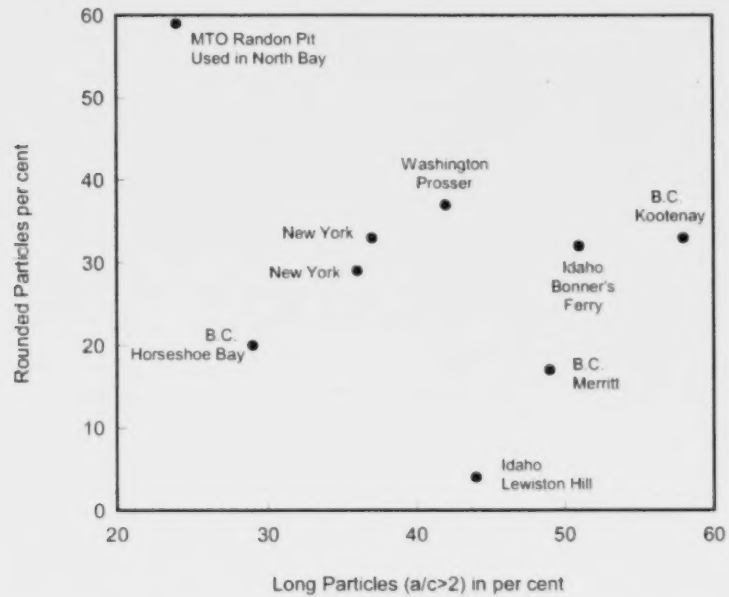


Figure 16. Long particles and rounded particles for a variety of truck arrester bed gravels sampled in 1999.

APPENDIX

Guide Specification for Truck Arrester Bed Aggregate

Modified from Ontario Provincial Standard and Specification Form 1004, 2006.

DEFINITIONS

Truck Arrester Bed Aggregate means a single-sized aggregate used in runaway truck lanes to slow and stop the progress of vehicles.

Long Particle means where the ratio of the greatest dimension in the longitudinal axis compared to the least dimension in a plane perpendicular to the longitudinal axis is less than 2:1.

Rounded Particle means particles having smooth rounded faces with no sharp edges or fractured faces and having the appearance of those particles shown in Figure 7 of ASTM D5821 or Figure 6 of MTO Test Method LS-607.

Truck Arrester Bed Aggregate

Truck arrester bed aggregate shall be uncrushed pit-run material meeting the gradation requirements shown in Table 1 and the physical requirements shown in Table 2. In addition, truck arrester bed aggregate shall meet the following shape requirements:

- a) Rounded particles shall be a minimum of 30% by mass. Rounded particles shall be determined by the procedure given in LS-607, reporting the percentage of rounded particles (defined above) instead of crushed particles. The test specimen size shall be a minimum of 200 particles passing the 37.5-mm sieve and retained on the 19-mm sieve.
- b) Long particles shall be a maximum of 50% by mass. Spheroidal particles shall be determined by the procedure given in LS-608, using a proportional caliper in which the ratio of the opening at one end to that at the other end is 2:1. The test specimen size shall be a minimum of 200 particles passing the 37.5-mm sieve and retained on the 19-mm sieve.

Table 1. Gradation Requirements for Truck Arrester Bed Aggregate

Sieve Size	Gradation (LS-602), Percent Passing
37.5 mm	100
19.0 mm	0 - 10
16.0 mm	0 - 5

Table 2. Physical Property Requirements for Truck Arrester Bed Aggregate

Laboratory Test	MTO Test Number	Truck Arrester Bed Aggregate
Loss by Washing, Pass 75 µm Sieve, % maximum	LS-601	1.0
Absorption, % maximum	LS-604	2.0
Freeze-Thaw Loss, % maximum	LS-614	6
Micro-Deval Abrasion Loss, coarse aggregate, % maximum	LS-618	21



